Sustainability as a Lens for Traditional Material Science Curriculums

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Abstract The theoretical and methodological foundations of the sciences and technologies are essential to the removal of barriers to achieving sustainable systems. The teachings of these concepts still lie in traditional academic disciplines such as engineering, science, and mathematics. This structure can often manifest significant barriers to progress in tackling challenging sustainability issues due to an absence of a multifaceted, interdisciplinary, systems approach. This work will explore approaches for using current sustainability issues and problems to introduce both systems thinking and traditional material science discipline specific learning objectives to the classroom. Specific examples will be illustrated for a diverse set of courses and curriculum. Results show such an approach can improve recruitment and retention results in addition to improved teaching outcomes.

Keywords Pedagogy · Engineering · Education · ABET

The theoretical and methodological foundations of the sciences and engineering are essential to the removal of barriers to achieving sustainable systems. The teachings of these concepts still lie in traditional academic disciplines such as engineering, science, and mathematics. This structure can often manifest significant barriers to progress in tackling challenging sustainability issues due to the absence of a multifaceted, interdisciplinary, systems approach.

Material science has a particularly relevant set of foundational courses that lend themselves to interesting sustainability integration. Material selection approaches and software have begun to incorporate both economic and environmental "properties" in the decision analysis, highlighting the tradeoffs made in real applications [1]. Thermodynamics and kinetics principles can be illustrated in interesting energy conversion examples for next-generation renewable energy storage and production technologies. Other important contributions exist in fundamentals of mining, processing, alloying, phase equilibria, material flow analysis, etc. A variety of recent research is available with additional innovative suggestions [4, 6, 8].

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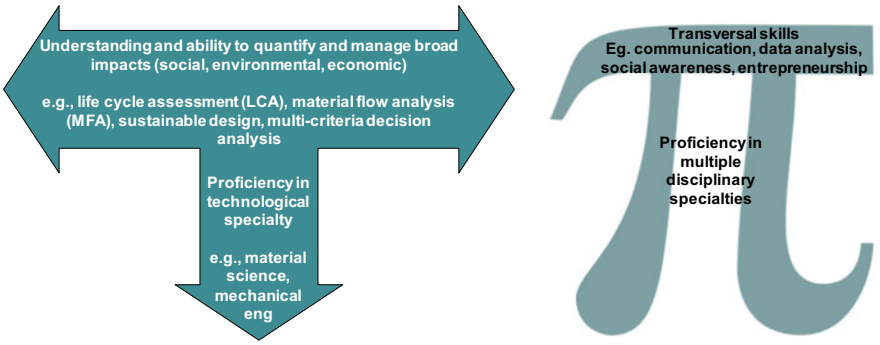

Fig. 1 Schematic representation of T-shaped and Pi-shaped competencies

Integration of sustainability issues into material science curriculum promotes nexus thinking. In many engineering curriculums, it can be challenging to promote interdisciplinary thinking when the curricular approach is inherently siloed. This can often lead to a reductionist spiral where "solutions" produce unintended consequences or additional problems. The famous inventor Thomas Midgeley is often used to illustrate such unintended consequences. While his introduction of MTBE to replace lead in automotive fuels was revolutionary and life-saving as it dramatically reduced emissions of lead to the air, the fuel additives he introduced have now been linked to endocrine disruption and ecotoxicity issues [11]. Another frequent example I give in class is the New York state rebate on new appliances. This rebate program was introduced to incentivize New Yorkers to replace older, less energy efficient appliances with newer ones in the hopes of reducing electricity consumption in the state. While the program was popular, it had the unintended consequence of a majority of participants buying a new refrigerator and keeping their old ones which actually increased appliance electricity consumption overall. Nexus thinking is a systems-based educational approach that ensures broader critical thinking skills; it promotes thinking through unintended consequences [7, 10].

Integration of sustainability into traditional disciplinary curriculums also promotes T-shaped or Pi-shaped student competencies (Fig. 1). Broad, transversal skills are being emphasized more by employers; it is imperative that today's student leave with not just a disciplinary degree but communication, organization, analysis, and critical thinking skillsets [2, 3]. These approaches also help to improve the translation of theory to practice, another key gap cited by employers. Students often struggle to take academic learning and use it directly for on the job skillsets; ABET has emphasized this need in its accreditation processes [5, 9].

Work presented at REWAS 2019 will explore approaches for using current sustainability issues and problems to introduce both systems thinking *and* traditional material science discipline-specific learning objectives to the classroom. Specific examples will be illustrated for a diverse set of courses and curriculum. Results show such an approach can contribute to improved recruitment and retention number and

preliminary results appear to also enhance student learning outcomes measured via traditional assessment methods.

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